Géographie physique et Quaternaire

The glacial and sea-level history of Darling Peninsula, eastern Ellesmere Island
L'histoire glaciaire et l'évolution du niveau marin de la péninsule de Darling, dans le'st de l'île d'Ellesmere.
Glaziale Geschichte und Entwicklung des Meeres-Niveaus der Halbindel Darling, östliche Ellesmere-Insel.

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Citer cet article

Gualtieri, L. (1998). The glacial and sea-level history of Darling Peninsula, eastern Ellesmere Island. *Géographie physique et Quaternaire*, *52*(3), 349–359. https://doi.org/10.7202/004830ar

Résumé de l'article

La reconstitution a été faite à partir des chenaux de fonte glaciaire et des moraines latérales mises en place par les glaciers locaux qui s'étendaient au large de la côte actuelle au cours du dernier maximum glaciaire. Au-dessus de ces moraines, le till coquillier et les erratiques en provenance du Groenland et de l'île d'Ellesmere témoignent de l'existence de glaciers plus étendus d'âge indéterminé. Les glaces d'Ellesmere ont alors emporté les glaces d'une bonne partie des côtes du Groenland, comme le démontre l'absence sur de grandes surfaces d'erratiques et de till coquillier au-dessus de la limite marine holocène. La chronologie de la déglaciation a été établie à partir des dates au ^{14}C obtenues sur des coquillages marins recueillis dans les deltas de contact glaciaire ou dans les plages soulevées près de la limite marine (à 79-88 m d'altitude). La déglaciation a commencé à partir de 7,5 ka BP et, à 6 ka BP, la répartition des glaces dans la péninsule était semblable à celle d'aujourd'hui. L'évolution du niveau marin de la péninsule a servi à établir les isobases sur les littoraux de 7,5 ka BP qui localement atteignaient 80-90 m d'altitude.

THE GLACIAL AND SEA-LEVEL HISTORY OF DARLING PENINSULA, EASTERN ELLESMERE ISLAND

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ABSTRACT   The glacial history of Darling Peninsula is recorded by meltwater channels and lateral moraines deposited by local ice that extended seaward of the present coast during the last glacial maximum. Above these moraines, shelly till and erratics of both Greenland and Ellesmere Island provenance record more extensive ice of unknown age. At the time of this more extensive ice cover, Ellesmere Island ice displaced Greenland ice from many parts of this coastline, as shown by the widespread absence of Greenland erratics and shelly tills above Holocene marine limit. The chronology of deglaciation is based on ^{14}C dates obtained on marine shells collected from either ice-contact deltas or raised beaches close to marine limit (79-88 m asl). Deglaciation began at least 7.5 ka BP and the distribution of ice on the peninsula was similar to present conditions by 6.0 ka BP. The reconstruction of the sea level history of Darling Peninsula contributes to the reconstruction of regional isobases drawn on 7.5 ka BP shorelines which locally reach 80-90 m asl.

RÉSUMÉ   *L'histoire glaciaire et l'évolution du niveau marin de la péninsule de Darling, dans l'est de l'île d'Ellesmere.* La reconstitution a été faite à partir des chenaux de fonte glaciaire et des moraines latérales mises en place par les glaciers locaux qui s'étendaient au large de la côte actuelle au cours du dernier maximum glaciaire. Au-dessus de ces moraines, le till coquillier et les erratiques en provenance du Groenland et de l'île d'Ellesmere témoignent de l'existence de glaciers plus étendus d'âge indéterminé. Les glaces d'Ellesmere ont alors emporté les glaces d'une bonne partie des côtes du Groenland, comme le démontre l'absence sur de grandes surfaces d'erratiques et de till coquillier au-dessus de la limite marine holocène. La chronologie de la déglaciation a été établie à partir des dates au ^{14}C obtenues sur des coquillages marins recueillis dans les deltas de contact glaciaire ou dans les plages soulevées près de la limite marine (à 79-88 m d'altitude). La déglaciation a commencé à partir de 7,5 ka BP et, à 6 ka BP, la répartition des glaces dans la péninsule était semblable à celle d'aujourd'hui. L'évolution du niveau marin de la péninsule a servi à établir les isobases sur les littoraux de 7,5 ka BP qui localement atteignaient 80-90 m d'altitude.

ZUSAMMENFASSUNG *Glaziale Geschichte und Entwicklung des Meeres-Niveaus der Halbindel Darling, östliche Ellesmere-Insel.* Die glaziale Geschichte der Darling-Halbinsel ist duch Schmelzwasser-Rinnen und seitliche Moränen aufgezeichnet, welche durch örtliches Eis abgelagert wurden, das sich während des letzten glazialen Maximums jenseits der gegenwärtigen Küste ausdehnte. Über diesen Moränen bezeugen Muschel-Till und erratisches Material sowohl von Grönland wie der Insel Ellesmere extensiveres Eis unbekannten Alters. Zur Zeit dieser extensiveren Eisdecke verdrängte Eis von der Ellesmere-Insel das Grönlandeis von vielen Teilen dieser Küstenlinie, wie aus dem Fehlen von erratischem Material und Muschel-Till aus Grönland über weite Flächen hin oberhalb der Holozän-Meeres-Grenze ersichtlich. Die Chronologie der Enteisung stützt sich auf ^{14}C-Daten, gewonnen von Meeres-Muscheln, die entweder von den Eis-Kontakt-Deltas oder angehobenen Stränden nahe an der marinen Grenze (79-88 m Höhe) gesammelt wurden. Die Enteisung begann mindestens 7.5 ka v.u.Z. und die Verteilung des Eises auf der Halbinsel war um 6.0 ka v.u.Z. den genwärtigen Bedingungen ähnlich. Die Rekons|truktion der Geschichte des Meeresspiegels der Darling-Halbinsel trägt zur Rekonstruktion der regionalen Isobasen an den Küstenlinien von 7.5 ka v.u.Z. bei, welche örtlich eine Höhe von 80-90 m erreichten.

INTRODUCTION

Two different reconstructions have been proposed for the extent of ice during the last glacial maximum (LGM) to the north and south of Darling Peninsula (England, 1976a, 1983, 1985, 1987; Blake, 1977, 1992a). The relationship between the amount of ice during the LGM and the amount of subsequent postglacial emergence has also been interpreted differently (*cf.* Tushingham, 1991; England *et al.*, 1991). One reconstruction favours a thick, regional ice sheet (the Innuitian Ice Sheet) over the eastern Queen Elizabeth Islands which coalesced with the Greenland and Laurentide ice sheets (Blake, 1970, 1992a, 1992b). Another reconstruction favours a discontinuous complex of glaciers and plateau ice caps (the Franklin Ice Complex) which left many fiords and channels ice-free, occupied by a full glacial Innuitian Sea (England, 1976a, 1990, 1992; Dyke and Prest, 1987). A regional database, reported from the mountainous eastern part of the Queen Elizabeth Islands has tended to favor the Franklin Ice Complex (Hodgson, 1985; Bednarski, 1986; Retelle, 1986; Lemmen, 1989; Evans, 1990; Sloan, 1990; Bell, 1992, 1996); however, evidence for more extensive ice in many areas remains undated. Until 1991, much of the east-central coast of Ellesmere Island had remained unstudied despite the fact that it borders ice-covered highlands from which part of the proposed Innuitian Ice Sheet dispersed (*cf.* Blake, 1992a). Recently, England (1996) has summarized the nature of the last glaciation and relative sea level adjustments along a 300 km transect of this coastline extending from Judge Daly Promontory to Kane Basin (Fig. 1). This study compliments this transect and reports additional fieldwork conducted along the western shore of Kane Basin, on Darling Peninsula (Figs.1 and 2). Specifically, this paper concerns the mapping of former ice margins and postglacial emergence in three valleys along the south coastline of Darling Peninsula. Darling Peninsula lies 125 km east of Humboldt Glacier (Greenland); hence, it provides the opportunity to investigate the interaction of Ellesmere Island and Greenland ice along this part of Kane Basin.

FIELD AREA

Darling Peninsula is oriented northeast/southwest, and is 45 km long and 20 km wide (Figs. 1 and 2). The Peninsula is bounded to the north by a valley joining the heads of Scoresby Bay to Dobbin Bay to the south. The area is characterized by mountains reaching 980 m asl which support small ice caps and valley glaciers. The regional glaciation level today is ~ 700 m asl (Miller *et al.*, 1975). Darling Peninsula occurs just to the north of the North Water polynya which favors higher precipitation and much lower glaciation levels (~ 500 m asl) along SE Ellesmere Island where 70% of the coastline is tidewater glaciers. Three valleys draining the south side of the peninsula were studied: Maury Bay, Gould Bay and west of Cape Louis Napolean, from east to west, respectively (Fig. 2). These ice-free lowlands contain diverse Quaternary landforms and sediments extending 5-
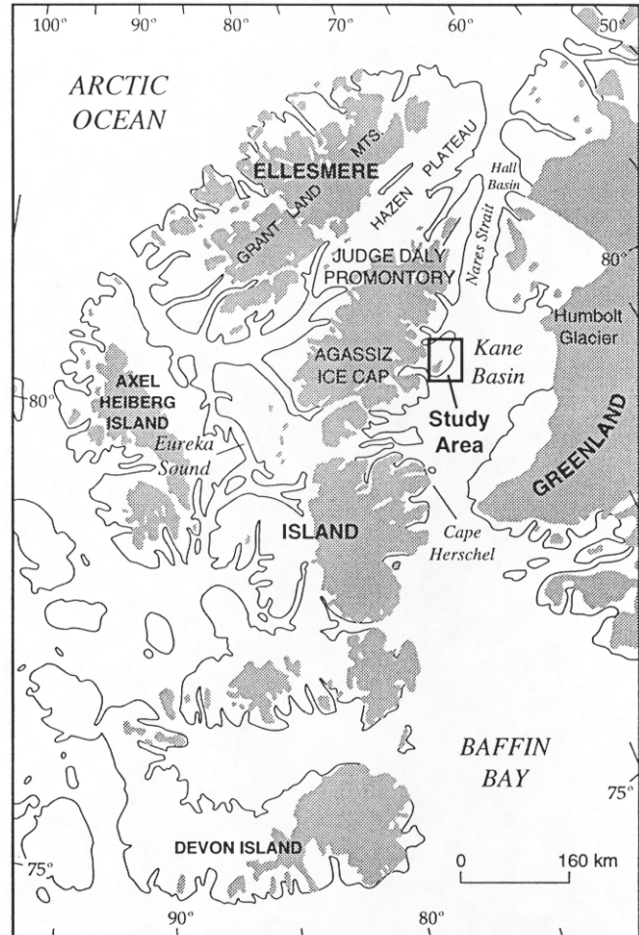

FIGURE 1.   Eastern Queen Elizabeth Islands, place names used in text, and study area. Present ice cover is shaded.
Partie est de l'archipel de la Reine-Élisabeth, toponymie et région à l'étude. Les glaciers actuels sont en grisé.

GEOMORPHOLOGY

The surficial geology was mapped primarily by air photo analysis and verified by transects across the peninsula (Fig. 2). The surficial geology and raised marine landforms are shown in Figure 3. A description of the map units is given below.

PRE-QUATERNARY

The Pre-Quaternary geology consists of weathered middle Proterozoic to Cenozoic (Paleocene) bedrock. Lithologies include dolomite, quartzose sandstone, conglomerate, limestone and shale. This sedimentary bedrock contrasts sharply with sparse Precambrian erratics from Greenland. Bedrock includes any of the above lithologies which form cliffs, ridges and isolated outcrops, some of which have been substantially weathered to felsenmeer and tors. Fine textured residuum also was mapped as bedrock.
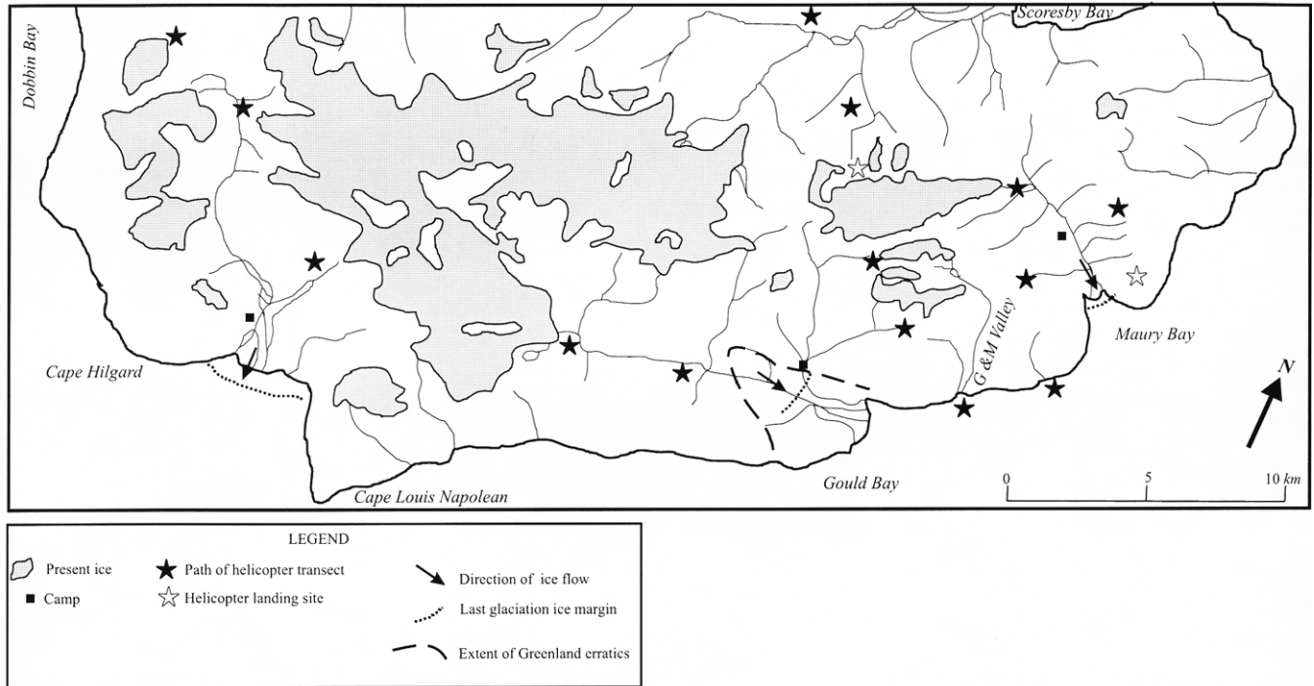
FIGURE 2.   Darling Peninsula camp locations (squares) and place names used in text. Stars represent helicopter transects and where landings were made. Present ice cover is shaded. The extent of Greenland ice on Darling Peninsula is shown by black dotted line. This limit is based on the distribution of Greenland erratics and shells found up to 315 m asl. The minimum extent of ice during the last glaciation in major valleys is represented by a stippled line and arrows mark the direction of former ice flow.

Emplacements des campements à la péninsule de Darling (carrés) et toponymie. Les étoiles noires montrent les transects effectués par hélicoptère. Les glaciers actuels sont en grisé. Les pointillés montrent l'extension des glaces du Groenland sur la péninsule. Cette limite est fondée sur la répartition des erratiques du Groenland et des coquilles trouvées jusqu'à une alttitude de 315 m. L'extension minimale des glaciers pendant la dernière glaciation dans les principales vallées est indiquée par une ligne brisée ; les flèches donnent la direction de l'ancien écoulement glaciaire.
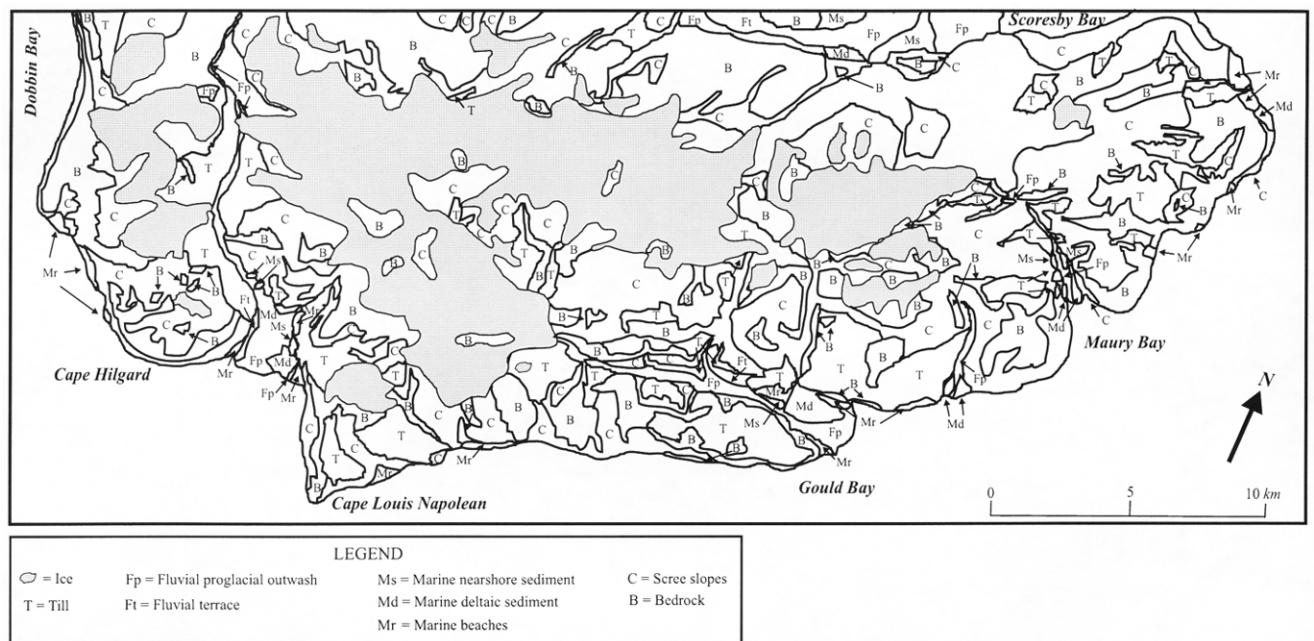

FIGURE 3.   Surficial Geology of Darling Peninsula. Present ice cover is shaded. Map units are described in detail in text.

Dépôts de surface à la péninsule de Darling. Les glaciers actuels sont en grisé. Les différentes unités sont décrites dans le texte.

GLACIAL

The most common and widespread sediment on Darling Peninsula is till. Till commonly consists of unsorted quartzose sandstone or limestone blocks in a sand or silt matrix. In some places, shells also constitute erratics within till. Mapping of till on air photos was done primarily by identifying areas where bedrock was mantled by coarse material. Till veneer is discontinuous and < 0.5 m thick. The surface of the till veneer mimics the shape of the underlying rock surface or structure (Dyke, 1983). Till on Darling Peninsula rarely reaches thicknesses > 0.5 m; therefore, no till blanket was mapped.

MARINE

Marine deposits consist of gravel, sand, silt and clay commonly containing whole valves or fragments of shells. Nearshore sediment includes silt and fine sand up to 1.5 m thick. It commonly contains whole valves of *Hiatella arctica* and *Mya truncata*. Deltaic sediment is dominantly sand and gravel displaying topset, foreset and bottomset beds typical of a Gilbert-type delta. These are normally dissected due to postglacial emergence. Some deltas on Darling Peninsula have well-preserved ice-pushed ridges on their coastal margins. Due to the high energy environment of such deltas, shells are sparse and commonly fragmented. Beach sediment includes gravel and shingle surfaces forming ridges 1.5 m thick. They normally contain shell fragments.

FLUVIAL

Fluvial sediments on the Peninsula are classified as active and inactive. Proglacial outwash includes sandar from modern glaciers which occupy most valleys, as well as alluvial fans. All active sandar on Darling Peninsula are depositing deltas into the sea. Terrace refers to inactive fluvial sediments that border modern sandar and record the progressive incision of these valleys due to continuous postglacial emergence since deglaciation.

COLLUVIUM

Colluvium represents a significant part of the surficial geology of Darling Peninsula and commonly obscures raised beaches and nearshore marine sediment. Colluvium includes talus mantling valley slopes, predominantly as aprons below cliffs. Rock glaciers are present, but not mapped on Figure 3. They include rock-glacierized moraines as well as talus mobilized by interstitial ice of meteoric rather than glacial origin. Evidence of downslope movement is mostly in the form of arcuate ridges and troughs leading to a steep lobate front. All the rock glaciers in the field area appear to be active.

ICE

Ice is widespread on the uplands of Darling Peninsula and includes plateau ice caps and outlet glaciers, as well as smaller cirque glaciers.

MARINE STRATIGRAPHY AND RADIOCARBON AGE ESTIMATES

RADIOCARBON AGE ESTIMATES

The chronology of deglaciation and relative sea-level on Darling Peninsula is based exclusively on radiocarbon dating of marine shells. *Hiatella. arctica* and *Mya truncata* were the most common species collected from beach gravel and nearshore sediment (Table I).

MAURY BAY

Greenland erratics are found only at or below marine limit throughout Maury Bay. Consequently, sea-ice or iceberg rafting must have been responsible for their distribution. The absence of Greenland erratics on the uplands surrounding Maury Bay (P1, P2, P3, Fig. 4) is puzzling because Greenland erratics (above marine limit) were found inland of Scoresby Bay *ca*. 10 km to the northwest (Fig. 2). Their occurrence in this interior valley suggests that they were transported northward across the Darling Peninsula divide which reaches ~ 1000 m asl. Alternatively, the erratics were deposited by Greenland ice inundating Scoresby Bay.

Prest (1952), after a brief visit to Maury Bay, described it mainly as stream-terraced outwash grading upward into kames and talus. He did not report beaches. During 1993,

TABLE I

Radiocarbon Dates for Darling Peninsula

Lab. No.	Material	Stratigraphy	*Age (years BP)	Sample Elev. (m)	Relative sea level (m)	Lat.N	Long. W
TO-4214	Shell Fragment	Marine silt	7430±70	71	83	7949'	7107'
TO-4209	Shell Fragment	Beach	6930±90	81	>81-88	7947'	7109'
TO-4210	Shell, *Hiatella arctica*	Beach	7480±60	75	>75-88	7945'	7122'
TO-4208	Shell Fragment	Marine silt	7110±70	75	80	7945'	7130'
TO-4212	Shell, *Mya truncata*	Delta surface	7040±70	61	79	7943'	7224'
TO-4211	Shell Fragment	Beach	7390±70	74	>74-79	7941'	7217'
TO-4213	Shell, *Hiatella arctica*	Beach	6020±60	63	>63-79	7940'	7205'

* Age corrected for a 410 year reservoir effect.

FIGURE 4. Maury Bay and G&M valley to the south showing ^{14}C dated sites and marine limit (ML). Meltwater channels (barbed arrow pointing up-ice) and moraines (black dotted line) record an outlet glacier occupying the bay sometime prior to 7430 BP (TO-4214). P1, P2 and P3 mark the uplands which are free of Greenland erratics. Aerial photograph A16611-115 © 1959 Her Majesty the Queen in Right of Canada, reproduced from the collection of the National Air Photo Library with permission of Natural Resources Canada.

Sites de datation au ^{14}C et limite marine (ML) dans la région de la baie de Maury et de la vallée G&M vers le sud. Les chenaux de fonte glaciaire (flèche pointant vers l'amont) et les moraines (points réunis par une ligne) témoignent d'une langue glaciaire occupant la baie quelque part avant 7430 BP (TO-4214). P1,P2 et P3 sont des sites en terrain élevé où il n'y a pas d'erratiques du Groenland. (Reproduction de la photographie aérienne A16611-115 © 1959 autorisée par Ressources naturelles Canada.)
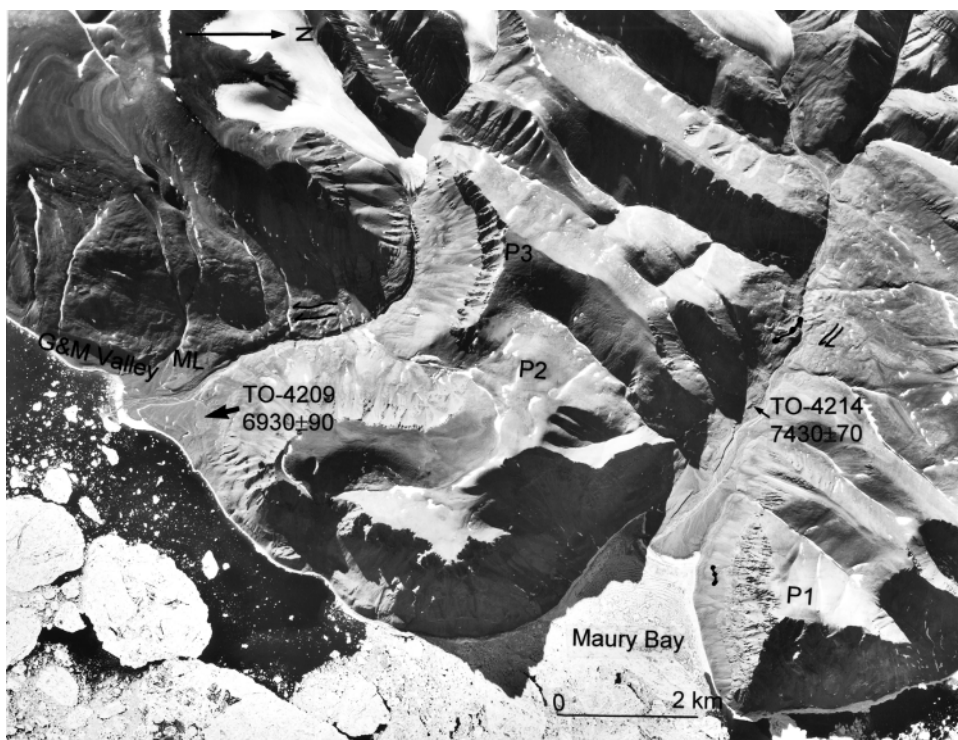
raised beaches, nearshore marine silt and deltas, all containing shells, were found inland of Maury Bay (Fig. 4). These landforms and sediments occur inside lateral moraines marking an outlet glacier within Maury Bay. The highest raised beaches (83 m asl) mark marine limit in this valley. Shell samples were collected on the surface of beaches and in nearshore marine sediments at elevations between 66 and 71 m asl. Shell fragments collected on the south side of the valley, from nearshore marine silt (1 m thick) at 71 m asl, dated 7430 ± 70 BP (TO-4214, Table I). This date provides a minimum age estimate on deglaciation and the establishment of marine limit.

G&M VALLEY

G&M valley occurs 6 km southwest of Maury Bay (Fig. 4). The south coast of the valley is characterized by raised beaches, sea ice-pushed ridges and abundant shells, although gelifluction has obscured the highest beaches. Shell fragments collected from beach gravel at 81 m asl dated 6930± 90 BP (TO-4209, Table I) and provide a minimum age estimate for marine limit (81 m asl).

GOULD BAY

Evidence for the advance of Greenland ice onto Darling Peninsula is widespread around Gould Bay (Figs. 5 and 6) where igneous and metamorphic erratics (granite, gneiss and garnetiferous schist) occur on the sedimentary terrane. High elevation lateral meltwater channels show that local ice infilled most of the main valley and its tributaries. Pink granite clasts, up to 10 cm in diameter, are found on the surface of the main delta in Gould Bay. West of the delta, at and below ~ 90 m asl, there is an increase in the number and variability of granite erratics. These erratics are assumed to record sea ice or ice-

berg rafting after the deglaciation of the valley, and their abundance may indicate widespread calving of Greenland ice nearby in Kane Basin. Unequivocal evidence for glacial transport occurs on the north flank of the main valley where Greenland erratics occur at 350 m asl (site U4, Fig. 6). North of the main delta, a few erratics were found in geliflucted till up to 95 m asl; however, only Ellesmere Island erratics (purple sandstone, conglomerate and pink quartzite) occur on the adjacent uplands (U2 and U3, 470 m asl, Figs. 5 and 6). Along the coast, north of Gould Bay, abundant gneiss and granite erratics occupy beaches up to approximately 50 m asl. Ascending the uplands south of the main valley (U1, Figs. 5 and 6) small Greenland erratics and shell fragments of *H. arctica* are found in till at 310 m asl. The Greenland erratics are absent in the col separating U1 from U2 and on top of U2, again suggesting preclusion by local Ellesmere Island ice immediately inland from the coast.

On the north side of Gould Bay the most striking feature is a high terrace at 124 m asl (Fig. 7a). This terrace sits above an ice-fed delta at 88 m asl (*Md*, Fig. 5) which is characterized by ice-pushed ridges along its outer edge. The lowermost meltwater channels terminate in the vicinity of the 88 m delta (Fig. 7b). The delta consists principally of coarse gravel. However, discernible topset, foreset and bottomset beds were not exposed. The origin of the 124 m terrace is uncertain. However the presence of till on its surface indicates that it was overrun by ice during the last glaciation. Elsewhere, beaches and marine silt range in elevation from 71 to 88 m asl. Shell fragments collected at 75 m asl, in nearshore marine silt, dated 7110 ± 70 BP (TO-4208) provide a minimum estimate for the 88 m delta. On the south coast of Gould Bay *Hiatella arctica* was found at 75 m asl and dated 7480 ± 60 (TO-4210).

CAPE LOUIS NAPOLEAN

Greenland erratics were not found on any of the peaks around Cape Louis Napolean (T1, T2, Fig. 8). Rather, Greenland clasts occur only at or below marine limit, indicating that Greenland ice was excluded by local Ellesmere Island ice. The most prominent landform on the west side of the valley is a discontinuous moraine 25 m in height, which reaches 88 m asl (Fig. 8). The moraine is trimmed by beaches up to 63 m asl which contain shell fragments. The mouth of the eastern tributary valley contains lateral moraines, till veneer and colluvium. Above the delta in the central part of the valley (*d1*, Fig. 8), the slope is dominated by moraines that have become rock glacierized. Three horizontal moraine segments, at approximately 60 m asl, extend to Cape Louis Napolean and suggest the presence of floating ice during deglaciation (Fig. 8).

The highest shoreline in the valley is marked by a delta composed of coarse sand and gravel at 79 m asl. Foreset beds are recognizable; however, topset beds were not observed. *Mya truncata* collected from the delta dated 7040 ± 70 BP (TO-4212, *d1*, Fig. 8.). West of this delta in a tributary valley, nearshore marine sediments contain shells between 58 and 62 m asl.

On the lower, east side of the main valley, a delta (*d2*, Fig. 8) overlies till-covered bedrock below a large ice-free cirque. The uppermost delta surface (> 100 m asl) is cryoturbated, weathered and partly obscured by till. Shell fragments occur at lower elevations (78 m asl), whereas valves of *Hiatella arctica* and *Mya truncata* (undated) occur in clay (36 m asl) interpreted to be bottomset beds of the delta (*d2*, Fig. 8). Beaches reaching 74 m asl, southeast of the delta, contain shell fragments dated 7390 ± 70 BP (TO-4211) which provide a minimum age for the delta. North of Cape Louis Napolean (2.5 km, Fig. 8) the highest beach occurs at 67 m asl. One shell fragment collected 4 m below this surface dated 6020 ± 60 BP (TO-4213).

DISCUSSION AND INTERPRETATION

THE LAST GLACIATION - ICE MARGINS

In all the investigated valleys, the prominent ice marginal landforms provide only a minimum ice limit during the LGM (Fig. 2). Ice in the Maury Bay and Cape Louis Napolean valleys extended seaward of the present coastlines, whereas landforms in Gould Bay occur 2-3 km inland from the coast. If more extensive ice occupied Gould Bay during the last glaciation, its depositional evidence occurs offshore. At most sites where ice contacted the sea, deltas and nearshore marine sediments are abundant and commonly associated with moraines and/or meltwater channels (Stewart, 1991).

FIGURE 5.   Gould Bay valley showing ^{14}C dated sites, marine limit delta (*Md*), meltwater channels (barbed arrows pointing up-ice) and till veneer (*Tv*). Greenland erratics were found on upland sites U1 and U4, but absent at sites U2 and U3. Aerial photograph A16610-5 © 1959 Her Majesty the Queen in Right of Canada, reproduced from the collection of the National Air Photo Library with permission of Natural Resources Canada.

Sites de datation au ^{14}C, delta de limite marine (Md), chenaux de fonte glaciaire (flèches pointant vers l'amont) et placage de till (Tv), dans la vallée de la baie de Gould. Des erratiques groenlandais ont été trouvés dans les sites de U1 et U4 en terrain élevé, mais pas aux sites U2 et U3. (Reproduction de la photographie aérienne A16610-5 © 1959 autorisée par Ressources naturelles Canada.)
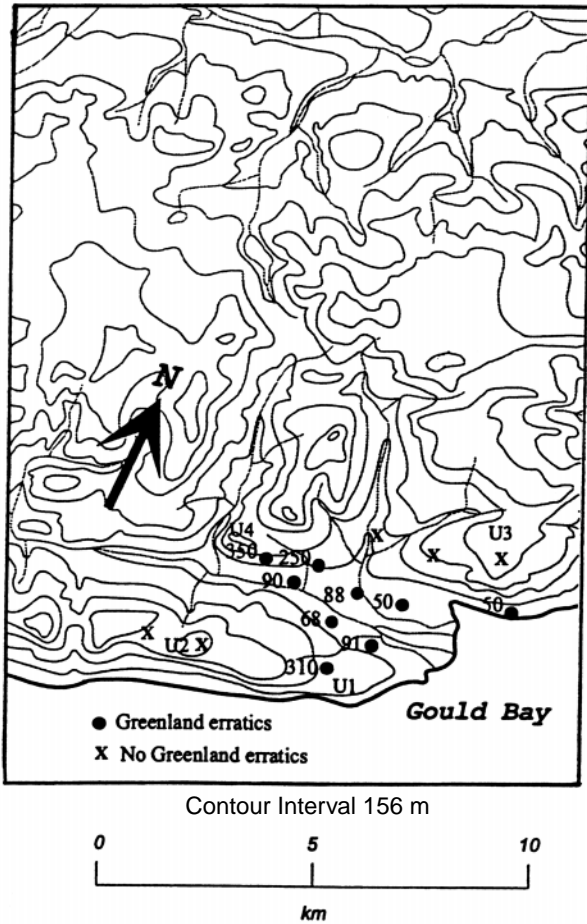
FIGURE 6.   Distribution of Greenland erratics in Gould Bay.

Répartition des erratiques du Groenland dans la région de la baie de Gould.

SEA-LEVEL HISTORY

Marine limit on Darling Peninsula ranges from 79 m (Cape Louis Napolean) to 88 m asl (Gould Bay). Because 6 out of the 7 radiocarbon dates fall between 7.0 and 7.5 ka BP, and their relative sea levels range from at least 74 to 83 m asl, it is concluded that the rate of emergence was slow (~ 5 m) during this 500 year interval. Similar evidence for slow initial emergence along eastern Ellesmere Island has been presented by England (1997).

Postglacial isobases drawn on the 8 ka BP shoreline on Ellesmere Island include a ridge of uplift extending northeastward from northern Eureka Sound (Fig. 1), paralleling the geologic structure and suggesting the possibility of a tectonic component to postglacial uplift (England, 1992, 1997). These isobases decrease in elevation toward the east coast from which they rise again towards Greenland (England, 1976b, 1985). The relatively low marine limits on Darling Peninsula (< 88 m), compared with surrounding areas, constitute a regional depression in the ~8 ka BP isobases.
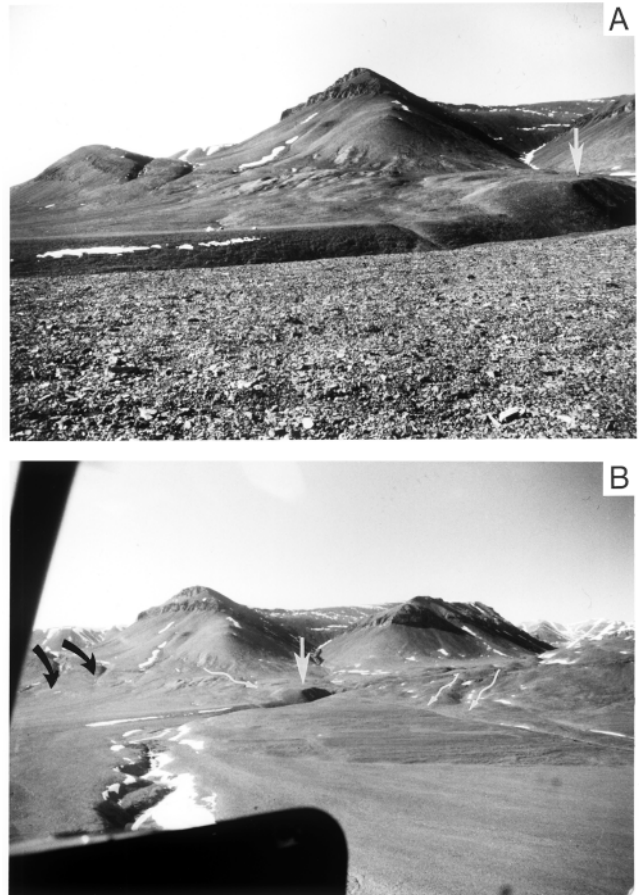

FIGURE 7.   A) Meltwater channels descending to delta at 88 m asl (minimum marine limit) in Gould Bay. White arrow marks the 124 m surface (maximum marine limit). Note camp for scale (left centre) on lower delta (88 m asl). B) 88 m delta in Gould Bay. Note higher terrace (124 m asl, white arrow). Prominent meltwater channels cross-cut hillside to east (right) of the 88 m delta and are outlined by white barbed arrows. Thick black arrows also outline meltwater channels.

A) Chenaux de fonte glaciaire descendant vers le delta à 88 m (limite marine minimale) dans la baie de Gould. La flèche blanche identifie la surface à 124 m (limite marine maximale). Vers le centre gauche, le campement sur le delta à 88 m donne l'échelle. B) Le delta à 88 m dans la région de la baie de Gould. Noter la terrasse plus élevée (124 m, flèche blanche). Des chenaux de fonte glaciaire soulignés par les flèches blanches traversent les collines vers l'est (droite) du delta à 88 m. Les flèches noires soulignent aussi des chenaux de fonte.

DEGLACIATION AND POSTGLACIAL EMERGENCE

The available ^{14}C dates provide minimum age estimates for the deglaciation of Maury Bay (7430 BP), Gould Bay (7480 BP) and Cape Louis Napolean (7390 BP). The similarity of these dates (Fig. 9) suggests that all three valleys were deglaciated in concert. The lack of ice-contact deltas in the lower parts of these valleys suggests that calving was an important process during deglaciation. Based on the elevation of deglacial moraines in these valleys, it is apparent that the depth of the sea closely approximated ice thickness which would have insured calving. Farther inland, at the mouths of tributary valleys, the first appearance of ice-contact deltas suggests that the ice stabilized once it had retreated into more shallow embayments. The lack of depositional evidence along former
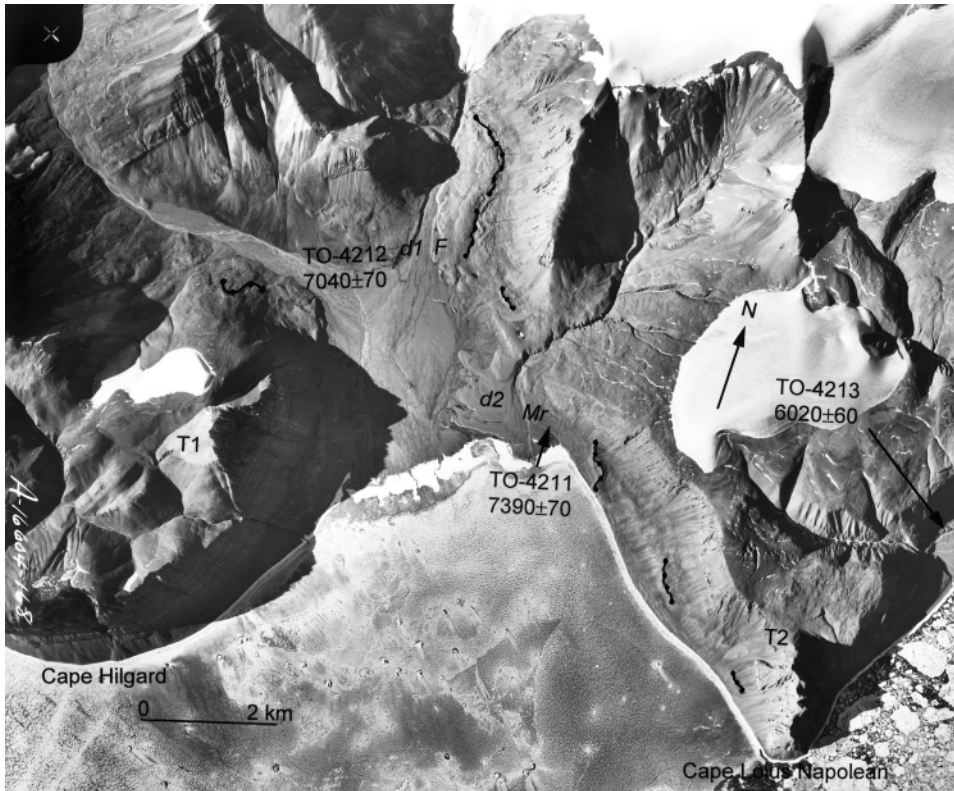
FIGURE 8. Cape Louis Napolean showing ^{14}C dated sites, deltas (*d1*, *d2*), moraines (black dotted lines), fluvial terrace (*F*) and beach ridges (*Mr*). Greenland erratics were absent on peaks T1 and T2. Aerial photograph A16604-168 © 1959 Her Majesty the Queen in Right of Canada, reproduced from the collection of the National Air Photo Library with permission of Natural Resources Canada.

Sites de datation au ^{14}C, deltas (d1, d2), moraines (points réunis par une ligne), terrasses fluviales (F) et levées de plage (M) dans la région du cap Louis-Napoléon. Il n'y a pas d'erratiques du Groenland aux sommets T1 et T2. (Reproduction de la photographie aérienne A16604-168 © 1959 autorisée par Ressources naturelles Canada.)
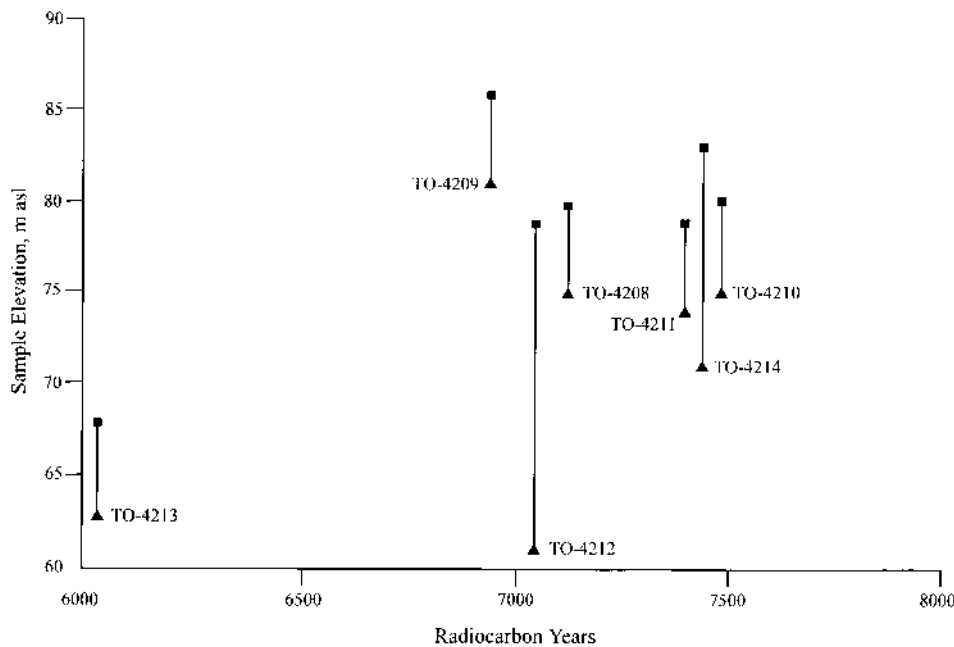

FIGURE 9. Elevations and associated relative sea levels for ^{14}C dated samples. Samples are plotted at the elevations where they were found (▲) and their corresponding relative sea levels are shown by squares. The relation is based on stratigraphic correlation between marine landforms (*e.g.* beach) and the sediment from which the shell was recovered.

Altitudes et niveaux marins relatifs correspondants de certains échantillons datés au [14]C. Les échantillons (▲) sont à l'altitude où ils ont été trouvés et le niveau marin correspondant est désigné par un carré. La relation est fondée sur la corrélation stratigraphique entre les formes marines (par ex., une plage) et le sédiment dans lequel le coquillage a été trouvé.

ice margins which were calving cautions against the conclusion that other areas without glacial sediments necessarily record ice-free conditions during the LGM. This remains a problematic issue in the Canadian High Arctic.

Compared with other dates on deglaciation and initial emergence from northern and eastern Ellesmere Island, Darling Peninsula fits into the regional pattern. For example, initial emergence of Robeson Channel, to the north, began between 8.6 - 8.0 ka BP (England, 1985; Retelle, 1986), and by 8.0 ka BP in Archer Fiord/Lady Franklin Bay, also to the north (England, 1983). In general, deglaciation was later (8.0 ka BP) on the south side of the Grant Land Mountains (Fig. 1) than it was to the north (10.0 ka BP), likely due to topoclimatic factors and glacier dynamics (England and Bednarski, 1986; Lemmen, 1989). Dyke and Prest (1987) show the ice margin

at 7.0 ka BP on Darling Peninsula to be similar to the present; however, it is likely that ice on the peninsula reached its present configuration around 6.0 ka BP or later, based on the delay in rapid unloading.

Postglacial emergence on Darling Peninsula was at least 88 m, and may have been >100 m at Cape Louis Napolean. These shorelines provide only a minimum measure of uplift since the LGM because an unknown amount of restrained rebound occurred prior to the entry of the sea during deglaciation (*cf.* Andrews, 1970; England, 1992). Furthermore, the observed emergence since 7.5 ka BP was countered by approximately 20 m of eustatic sea level rise (Fairbanks, 1989) Hence, a minimum of 108-120 m of postglacial uplift has occurred on Darling Peninsula since 7.5 ka BP. The similarity in the age and elevation of marine limit along the south shore of Darling Peninsula suggests that this coastline parallels an isobase oriented NE-SW.

Blake (1992a, 1992b) concluded that the entire area of southeast Ellesmere Island was covered during the LGM by coalescent Greenland and Ellesmere Island ice. He also reports a total of 140 m of emergence since 9 ka BP at Cape Herschel, of which 40 m presumably occurred between 8 ka and 7 ka BP. Our study does not indicate a similar rate of initial emergence on Darling Peninsula. For example, at Gould Bay, a shoreline at 63 m asl contains shells dated 6 ka BP which are within 25 m of marine limit (with a minimum date of 7.5 ka, Fig. 9). Based on a marine limit of 88 m asl, only 25 m of emergence occurred in the first 1500 years following deglaciation. The 100 m delta at Cape Louis Napolean would increase the emergence during the same interval by 12 m (*i.e.*, to 37 m). In either case, the rate of initial emer-

gence for Darling Peninsula appears to be < 3 m/100 years, which is unusually slow for recently deglaciated sites (see England 1997). Because Darling Peninsula is adjacent to Humboldt Glacier — the principal source of Greenland ice which reached the more distant site of Cape Herschel during the last glaciation (Blake, 1977) — it remains unclear why more rapid emergence would have occurred at Cape Herschel than on Darling Peninsula (between 8 ka and 7 ka BP). Cape Herschel was also deglaciated earlier (~ 9 ka BP, Blake 1992a). Although faults are reported on Darling Peninsula, as well as other localities along eastern Ellesmere Island (Mayr and DeVries, 1982), it is unclear whether there have been any tectonic effects on the uplift of this area during the Holocene. Cape Herschel also occurs within the Precambrian shield and hence its rheological response to glacial unloading may differ from that of sedimentary rocks of the Franklinian Mobile Belt (Trettin, 1989) which comprises Darling Peninsula.

FORMER GLACIATION (S)

The Greenland Ice Cap extended onto much of the east coast of Ellesmere Island, advancing northward and southward from Kane Basin, and depositing distinctive Precambrian erratics onto the sedimentary terrane of the Franklinian Mobile Belt (*cf.* Christie, 1967; Blake, 1977; England *et al.*, 1978, 1981; Lemmen and England, 1992). The relationship between the distribution of Greenland erratics and marine limit observed on Darling Peninsula is shown in Figure 10. Blake (1970, 1977, 1978, 1992b) proposed that the inundation of Kane Basin took place during the LGM, whereas England and Bradley (1978) proposed a date of > 35 ka for
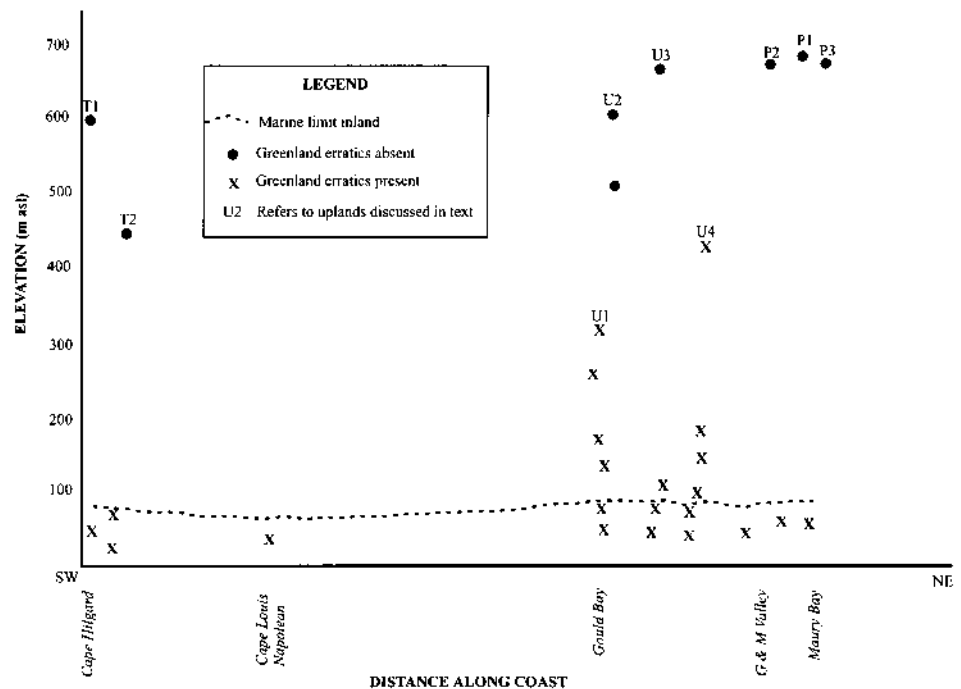

FIGURE 10. The relationship between the distribution of Greenland erratics and marine limit on Darling Peninsula. Greenland erratics were present *above* marine limit only at three areas in Gould Bay.

La relation entre la répartition des erratiques du Groenland et la limite marine à la péninsule de Darling. Les erratiques du Groenland étaient présents au-dessus de la limite marine à seulement trois emplacements de la baie de Gould.

the advance of Greenland ice onto northeast Ellesmere Island. More recently, Lemmen and England (1992) suggested an age of > 40 ka for the coalescence of Greenland and Ellesmere Island ice in northern Nares Strait and further proposed, on glacioclimatic grounds, that it may have occurred during a period of reduced sea ice cover on the Arctic Ocean.

The upper limit of glaciation on the Peninsula is marked by the distribution of Greenland and Ellesmere Island erratics, including the presence of shells found more than 200 m above Holocene marine limit. Since Greenland erratics are found *above* marine limit only at Gould Bay, it is concluded that Greenland ice substantially inundated only this part of the Peninsula (Fig. 2). This probably records a complex interfingering of Ellesmere Island and Greenland ice whose point of coalescence was predominantly seaward of the present coast in this area. The potential for a strong outflow of Ellesmere Island ice is manifested today by the extensive icefields encircling Dobbin Bay and the advance of this ice may explain the apparent deflection of the Greenland ice from most of the uplands of Darling Peninsula.

Shorelines formed during deglaciations predating the LGM have been reported at a few localities to the north of Darling Peninsula (England *et al.*, 1978, 1981; Retelle, 1986; Lemmen and England, 1992); however, unequivocal evidence for similar shorelines was not observed on Darling Peninsula. The till-covered terrace in Gould Bay (124 m asl, Fig. 7a) may be a remnant of a pre-Holocene shoreline and warrants further study. This surface is 36 m above the proposed Holocene marine limit (88 m). An alternative interpretation for the 124 m terrace in Gould Bay, as well as the ~ 100 m delta at Cape Louis Napolean, is that these record Holocene marine limit. However, the uppermost limit of Holocene shells reported here consistently occurs at 85 ± 5 m asl. Furthermore, these higher surfaces (100 and 124 m asl) are covered with till. Consequently, these surfaces were overridden by ice sometime during the last glaciation.

SUMMARY

During the last glaciation of Darling Peninsula, cirque and outlet glaciers occupied valleys and cols extending seaward of the coast. A paleoglaciation level for the Peninsula is estimated at 470 m asl, based on the elevation of ice-free uplands on the north side of Gould Bay that were occupied by local ice caps during the last glaciation. The North Water polynya was likely the main precipitation source for these glaciers prior to 7.5 ka BP. Meltwater channels and lateral moraines record outlet glaciers in the lower valleys which had a minimum thickness of 140 m. Because relative sea level was at least 88 m above present during deglaciation, initial ice retreat was characterized by widespread calving as these outlet glaciers became thinner. Little glaciomarine sedimentation occurred in this calving zone and this cautions against the potential interpretation that such sites remained unglaciated during the LGM. Farther inland, in shallower water, ice-contact deltas commonly record the subsequent

stabilization of ice margins once they had become grounded. Marine limit was attained by at least 7.5-7.0 ka BP after which emergence progressed slowly until as late as 6.0 ka BP. It is difficult to speculate on factors that might have influenced the slow rate of initial emergence including uplift resulting from more than one ice mass (Greenland or Ellesmere Island) and possible tectonic effects. Dates on marine shells along the east coast of Darling Peninsula indicate that the 7.5 ka BP isobases range from 80-90 m asl, and parallel the coastline. During a regionally extensive glaciation of unknown age, only a small part of the Peninsula was inundated by Greenland ice which was otherwise displaced by the vigorous outflow of Ellesmere Island ice into Kane Basin.

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